OSAT Partners:
Cooperative Institute for Limnology and Ecosystems Research
IOOS/Great Lakes Observing System Regional Association
Regional Water Intake Managers
National Marine Sanctuaries
Regional National Weather Service Marine Weather Forecast Offices
Michigan Tech University
Michigan Tech Research Institute
University of Toledo Lake Erie Center
National Ocean Service/National Centers for Coastal Ocean Science
Oceans and Atmospheric Research/Earth Systems Research Laboratory
Grand Valley State University
Cooperative Institute for Research in Environmental Sciences

This work aligns with the following NOAA Goals:
Science: Climate Adaptation and Mitigation
Improved scientific understanding of the changing climate system and its impacts
Science: Weather-Ready Nation
Reduced loss of life, property, and disruption from high-impact events
Improve freshwater resource management
Improve transportation efficiency and safety
Healthy people and communities due to improved air and water quality services
A more productive and efficient economy through information relevant to key sectors of the U.S. economy
Science: Healthy Oceans
Improved understanding of ecosystems to inform resource management decisions
Healthy habitats that sustain resilient and thriving marine resources and communities
S**cience: Resilient Coastal Communities and Economies**
Resilient coastal communities that can adapt to the impacts of hazards and climate change
Comprehensive ocean and coastal planning and management
Safe, efficient and environmentally sound marine transportation
Improved coastal water quality supporting human health and coastal ecosystem services
Education: Science-Informed Society
Youth and adults from all backgrounds improve their understanding of NOAA-related sciences by participating in education and outreach opportunities
Formal and informal educators integrate NOAA-related sciences into their curricula, practices, and programs
Formal and informal education organizations integrate NOAA-related science content and collaborate with NOAA scientists on the development of exhibits, media, materials, and programs that support NOAA's mission
Education: Safety and Preparedness
Youth and adults from all backgrounds are aware of, prepare for, and appropriately respond to environmental hazards that impact health, safety, and the economy in their communities
Formal and informal educators use and produce education materials and programs that integrate and promote consistent science-based messaging on hazards, impacts, and societal challenges related to water, weather, and climate
Formal and informal education institutions integrate water, weather, and climate hazard awareness, preparedness, and response information into curricula, exhibits, and programs that create learning opportunities for youth and adults

Photos:
Top Left: Toledo Light 2
Bottom Left: Steve Constant works on an anemometer on the Chicago Met Station.
Bottom Right: Ron Muzzi demonstrates at the Command and Control Center for Real-Time Meteorological Observation Station

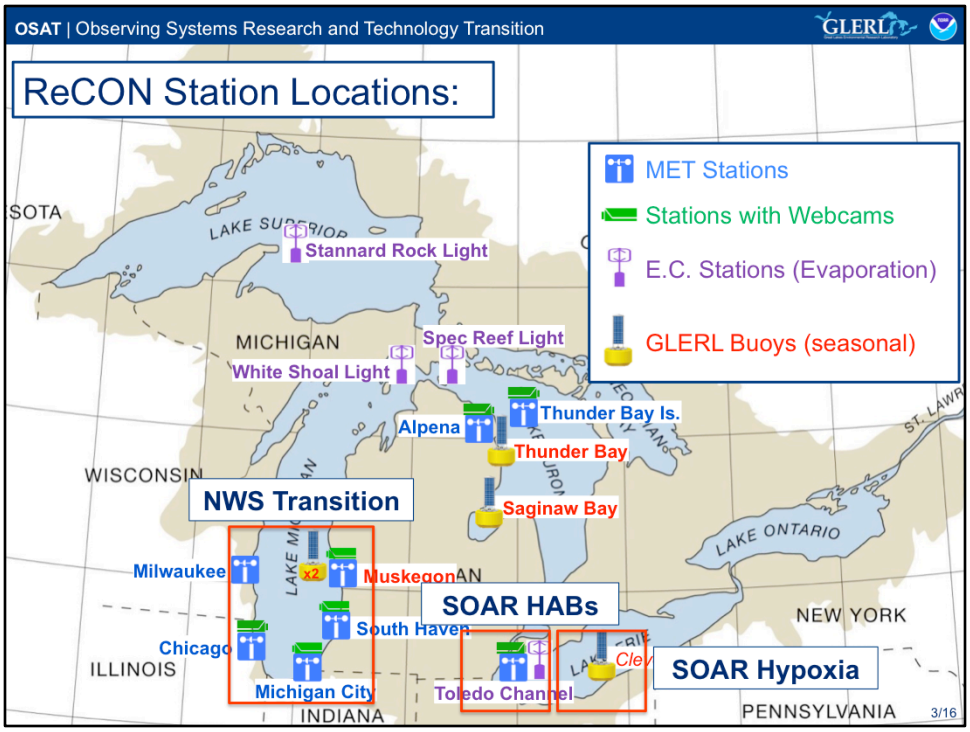
The Synthesis, Observations and Response (SOAR) project addresses Great Lakes Restoration Initiative (GLRI) adaptive management needs under Great Lakes Water Quality Agreement (GLWQA) Annex 4:

Lake Ecosystem Objectives of Great Lakes Water Quality Agreement Annex 4 - Canada/U.S. Phosphorus Load Reduction Targets

Minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie
- 40% reduction in total phosphorus entering the Western Basin and Central Basin of Lake Erie – from the United States and from Canada - to achieve 6000 MT Central Basin load

Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes
- 40% reduction in spring total and soluble reactive phosphorus loads from Canada/U.S. watersheds

Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes
- 40 % reduction in spring total and soluble reactive phosphorus loads from the Maumee River (U.S.)



ReCON: Real-Time Meteorological Observation Network – www.glerl.noaa.gov/metadata

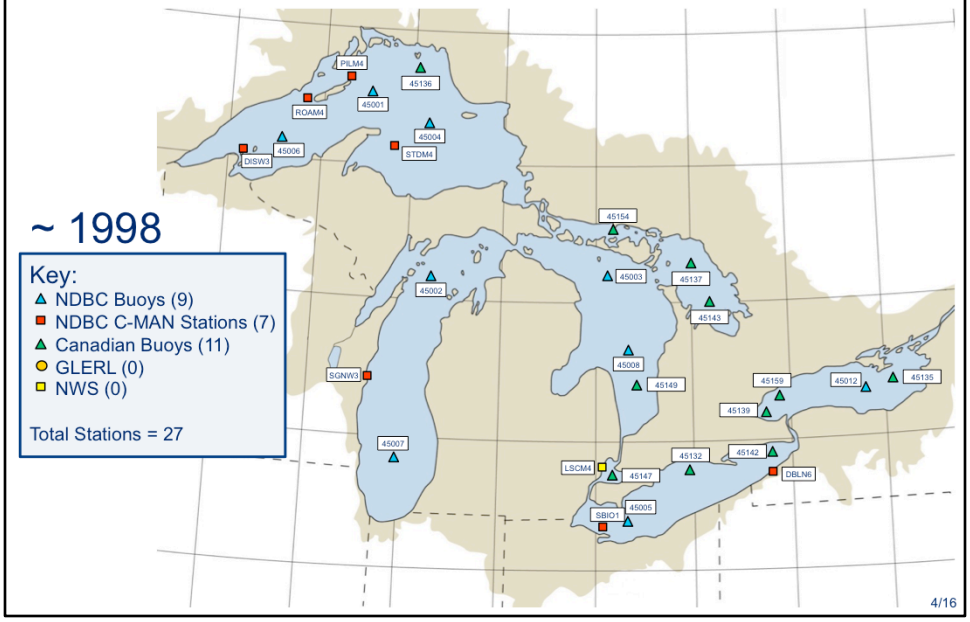
The southern Lake Michigan met stations were used to transition technology to NWS Central and Eastern regions that greatly increased the number of near shore observing nodes. Data from buoys, pier-based met stations and evaporation stations is used operationally by the GLOS RA* and NDBC (National Data Buoy Center).

GLERL's experience in advancing observational technology has led to:
. Invited talk at International Association for Great Lakes Research on session on *Monitoring Technologies for Assessing the Health of the Great Lakes* which will provide feedback to the International Joint Commission's Great Lakes Science Advisory Board.
. Invitation from NOAA/IOOS** to National Moored Data Buoy Plan Workshop
. Invitation from NOAA/NDBC Deputy Director to discuss potential for deployment of year-round, under ice observing nodes

*GLOS RA is one of 11 Regional Associations of the Integrated Ocean Observing System (IOOS)).
**IOOS is a partnership among federal, regional, academic and private sector parties that works to provide new tools and forecasts to improve safety, enhance the economy, and protect the environment.

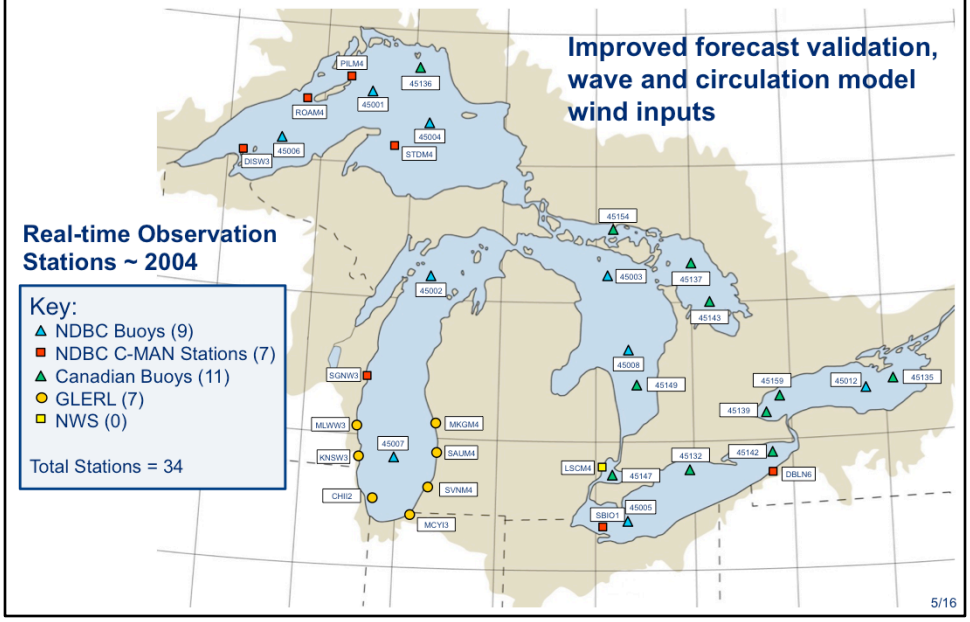
OSAT | Observing Systems Research and Technology Transition

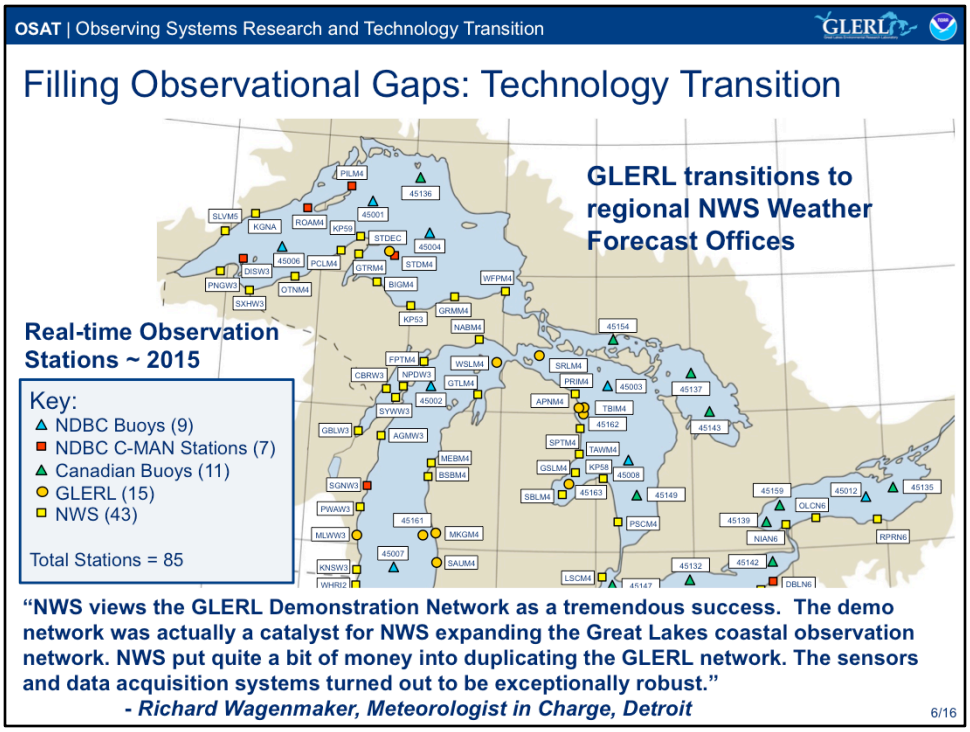
Filling Observational Gaps: Minimal coastal coverage



OSAT | Observing Systems Research and Technology Transition

Filling Observational Gaps: NWS collaboration





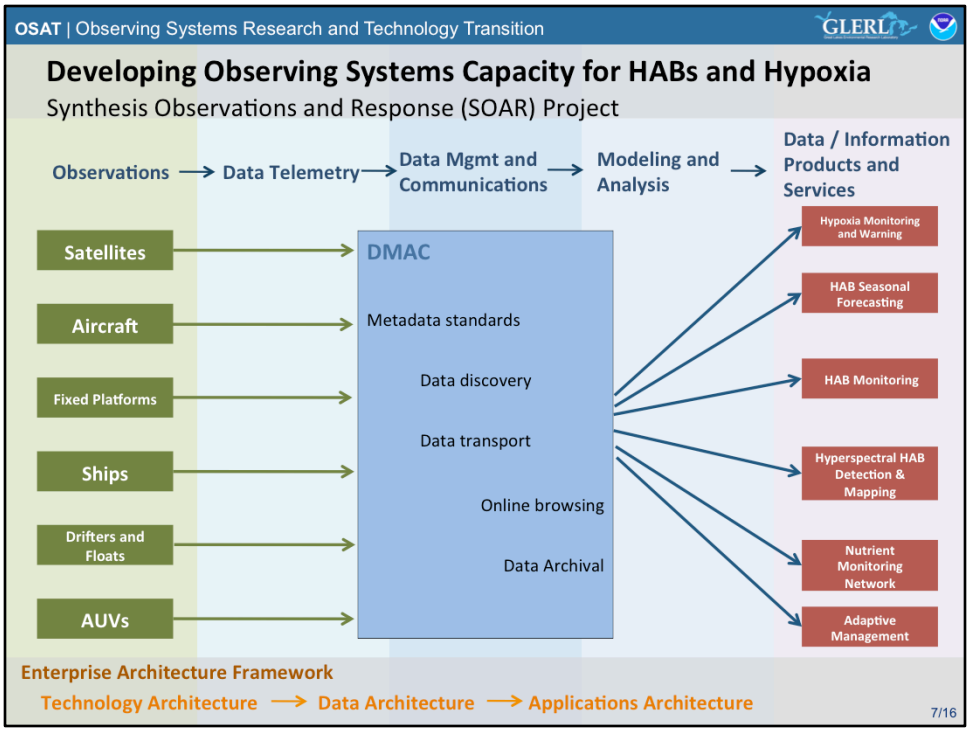
"NWS views the GLERL Demonstration Network as a tremendous success. The demo network was actually a catalyst for NWS expanding the Great Lakes coastal observation network. NWS put quite a bit of money into duplicating the GLERL network. The sensors and data acquisition systems turned out to be exceptionally robust." - Richard Wagenmaker, Meteorologist in Charge, Detroit

These sites provide real-time conditions for commercial shipping and recreational users. NWS users benefit from imagery. The GLERL website receives over 1 million unique web hits per year.

Collaborations: NWS, Thunder Bay National Marine Sanctuary, Great Lakes Observing System Regional Association

Future Work: Extend to year-round, cabled systems at offshore and pier-based stations

Due to the contributions of NOS CO-OPS, GLOS RA, Universities, and GLRI, the observation network has now grown beyond this state. This slide is intended to show GLERL's contribution to the NWS WFO marine observations expansion.

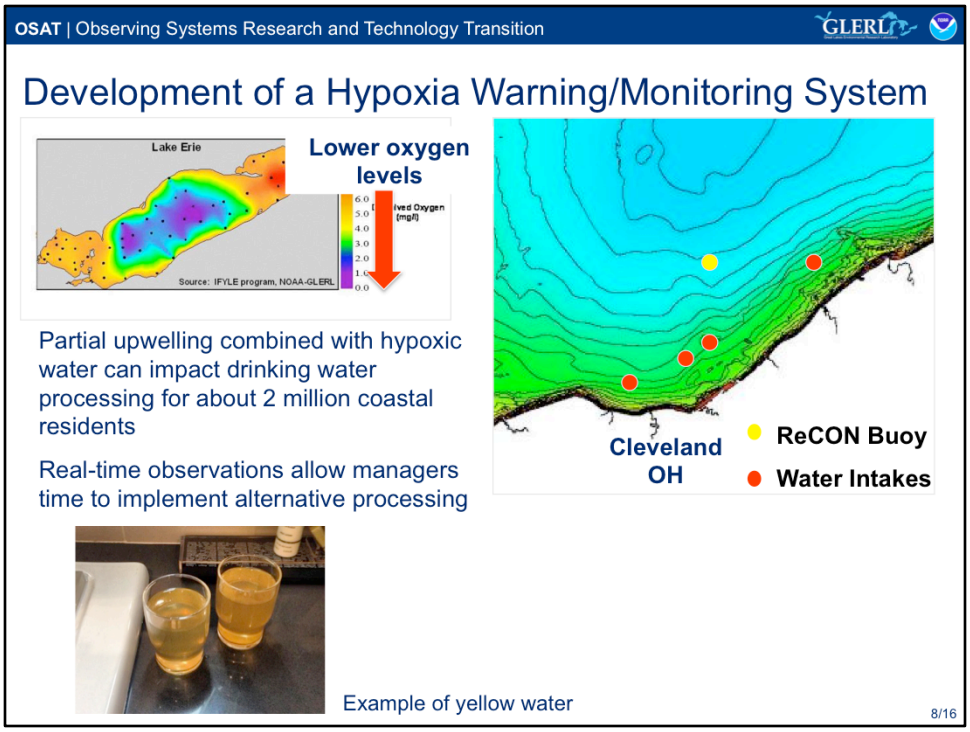


This project was initiated under the Great Lakes Restoration Initiative (GLRI). Through collaborations with federal, university and industry partners we have transitioned products and services into operation and application.

NOAA-GLERL received funding in 2010 under the GLRI to develop a near term design for the Great Lakes Observing System (GLOS) Enterprise Architecture. The GLOS Enterprise Architecture (EA) project scoped an integrated, holistic ecosystem observing system including the physical, chemical, and biological data collection necessary to support effective Great Lakes management. The EA focused on developing a system to observe change in the Great Lakes coastal environment resulting from the basin-wide implementation of the GLRI. A strategic plan was created for the near term GLOS enterprise design. The strategic plan is intended to leverage and build on the foundation of the existing programs and initiatives of GLOS, IOOS, NOAA-GLERL, and the GLRI. The EA final report provides recommendations for the design and implementation of prioritized elements of the system over the near term (next 5 years) towards a sustainable Great Lakes observing system over the long term. The EA report was a culmination of a multi-stakeholder collaborative effort with input and direction obtained directly from an expert advisory panel representing NOAA-GLERL, USEPA, USGS, USACE, and IOOS, as well as input provided to GLOS by numerous stakeholders over the past several years.

The Synthesis, Observations and Response (SOAR) project addresses Great Lakes Restoration Initiative (GLRI) adaptive management needs under Great Lakes Water Quality Agreement (GLWQA) Annex 4:

Lake Ecosystem Objectives of Great Lakes Water Quality Agreement Annex 4 - Canada/U.S. Phosphorus Load Reduction Targets
. Minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie
- 40% reduction in total phosphorus entering the Western Basin and Central Basin of Lake Erie – from the United States and from Canada - to achieve 6000 MT (metric ton) Central Basin load
. Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes
- 40% reduction in spring total and soluble reactive phosphorus loads from Canada/U.S. watersheds
. Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes
- 40 % reduction in spring total and soluble reactive phosphorus loads from the Maumee River (U.S.)

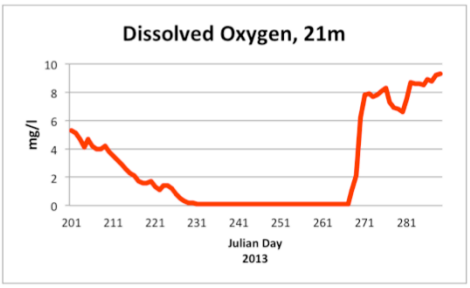


The Hypoxia Monitoring and Warning System provides observations for GLRI adaptive management and environmental intelligence for water intake managers in the central basin of Lake Erie. The central basin of Lake Erie hypoxic zone is the second largest in the US. The system provides time-series observations of oxygen and temperature relevant to water intake managers but also provides winds, waves, and currents important for commercial and recreational use and important in understanding the physics of hypoxia formation and hypolimnion movement.

Collaborations: US Environmental Protection Agency, United States Geological Survey, Great Lakes Observing System Regional Association, Limnotech

RUBERG, S.A., E. Guasp, N. HAWLEY, R.W. MUZZI, S.B. BRANDT, H.A. VANDERPLOEG, J.C. LANE, T.C. MILLER, and S.A. CONSTANT**.** Societal benefits of the real-time coastal observation network (ReCON): Implications for municipal drinking water quality.*Marine Technology Society Journal* 42(3):103-109 (2008).

Hypoxia Warning/Monitoring System



Cleveland Water Dept. (CWD) Decision Criteria:

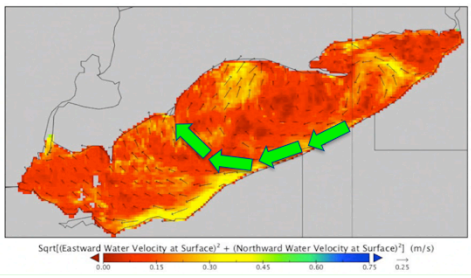
1. Real-time buoy indicates hypolimnion oxygen levels below 2 mg/l.

   Decision: stage KMnO4 and increase monitoring from 2 hours to 30 minutes.

2. Coastal surface currents forecast or detection of Mn at intake

   Decision: change treatment technique to include pre-oxidation with KMnO4

Currents: Great Lakes Coastal Forecasting System



- **Transitioned to GLOS Regional Association for operations**
- **Funded by CWD**
- **Buoy deployed by LimnoTech**
- **Sustainable ecosystem monitoring for Great Lakes Restoration Initiative Adaptive Management Process**

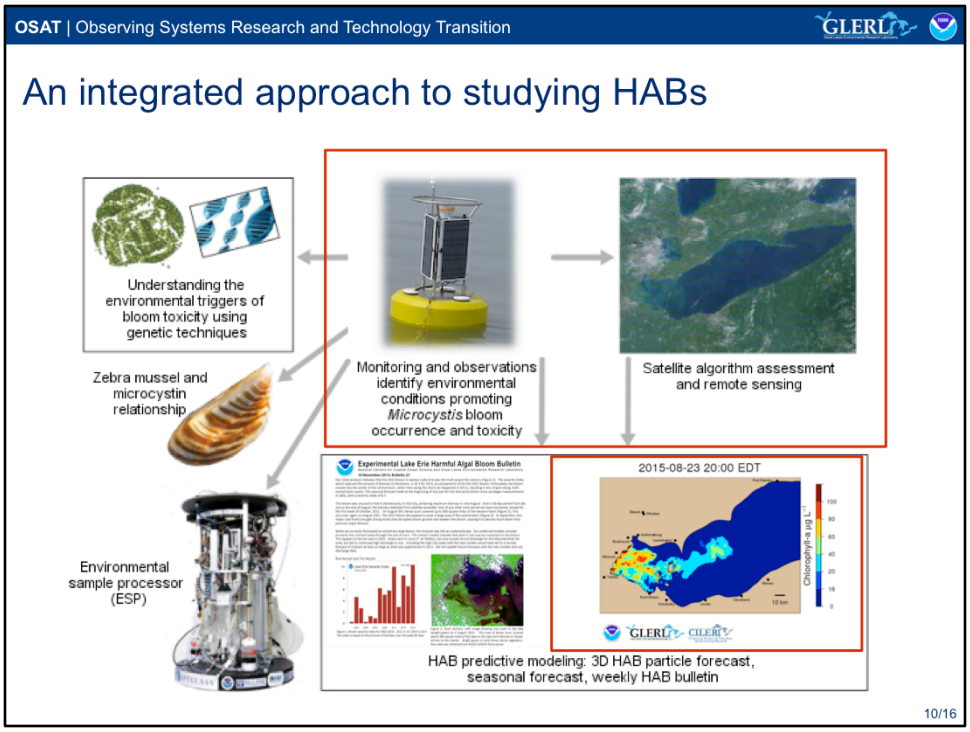
9/16

GLOS is an Integrated Ocean Observing System (IOOS) regional association

GLOS put out a competitive RFP, GLERL created the specification, and LimnoTech received the award.

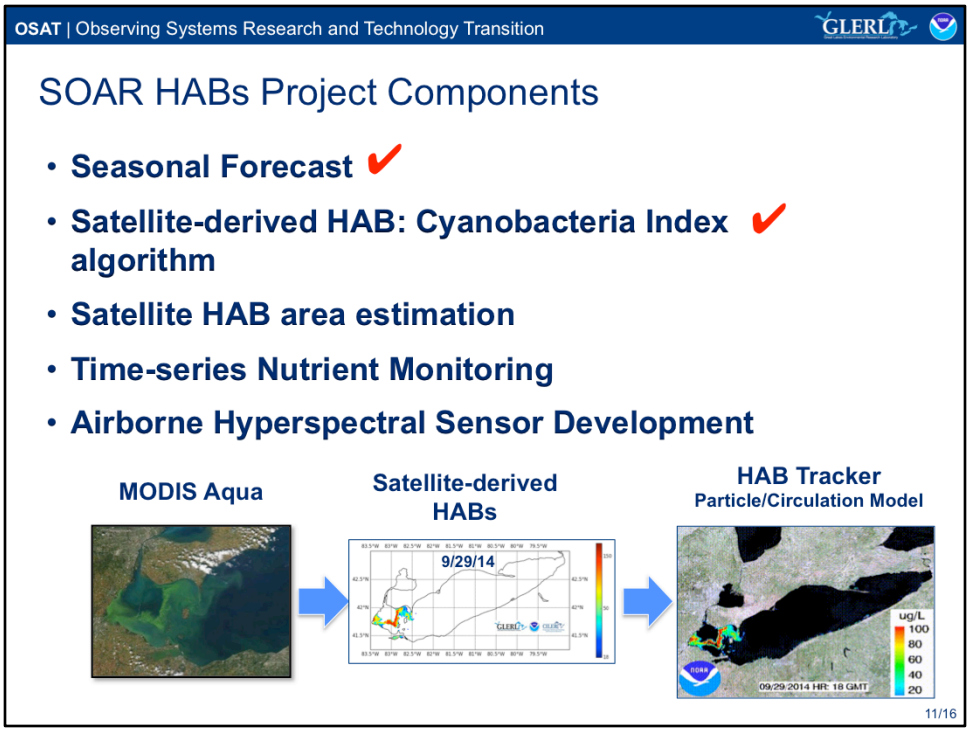
LimnoTech is a consulting company.

Future Work: Dissolved oxygen modeling, FVCOM dissolved oxygen layer movement forecast.



Overarching research statement:
Understanding the drivers of bloom ecology will aid in enhancing predictive models that forecast bloom size, location AND toxicity

HAB (Harmful Algal Blooms)



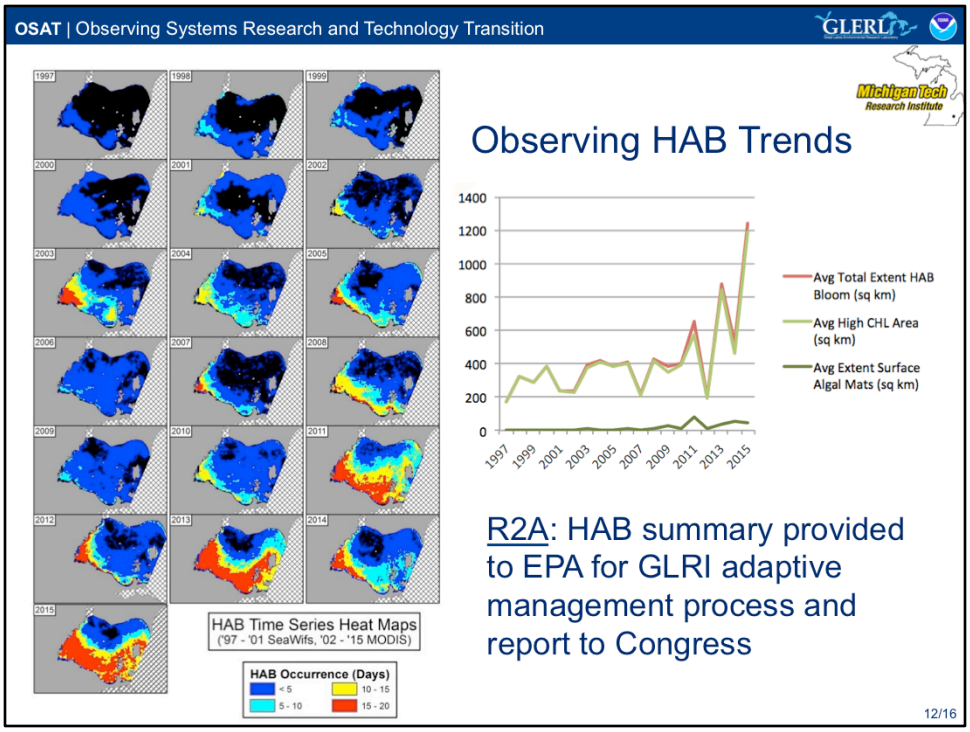
Seasonal Forecast: Re-developed the bloom/TP load relationship (NOS/NCCOS, Stumpf et al) within a statistical framework where uncertainty is represented quantitatively. The model is capable of assessing the critical loading period (loads prior to February contribute minimally). Gradual decline in threshold required to stimulate large blooms. **R2X: Seasonal forecasts (2014 and 2015 ensemble forecast); applied to set P loading targets for the Great Lakes Water Quality Agreement Annex 4.**

- Publication: Obenour, D.R., A.D. Gronewold, C.A. Stow, & D. Scavia. (**2014**). Using a Bayesian hierarchical model to improve Lake Erie cyanobacteria bloom forecasts. *Water Resources Research*
- Model has been used to make seasonal forecasts (2014 and 2015) and has been used to develop revised phosphorus loading targets for Annex 4 of the Great Lakes Water Quality Agreement.
- Work done in collaboration with University of Michigan Water Center in the Graham Sustainability Institute

Project data and information is displayed on the Experimental HABs and Hypoxia web page on the GLERL website, http://www.glerl.noaa.gov/res/HABs_and_Hypoxia/

National Ocean Service (NOS) / National Centers for Coastal Ocean Science (NCCOS)

HAB (Harmful Algal Bloom)



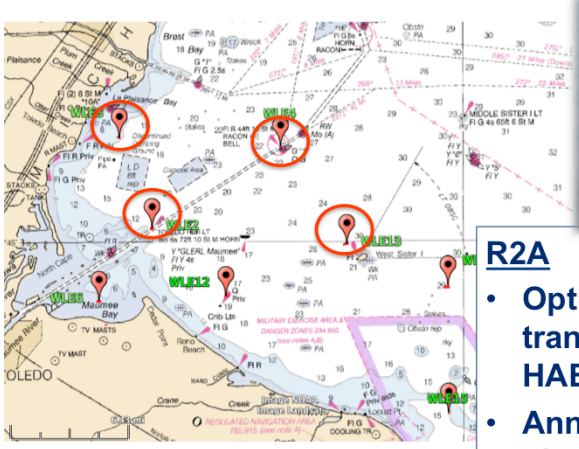
This data is created using a MODIS satellite processing algorithm developed by George Leshkevich, GLERL, and Robert Shuchman, Michigan Tech Research Institute.

Time-series of heat map images and areal extent (sq. km) plot for the western basin of Lake Erie near Toledo, OH
- SeaWIFS 1997-2004
- MODIS 2002-2015

HAB: Harmful algal blooms

Establishing Western Lake Erie Nutrient Monitoring Capacity

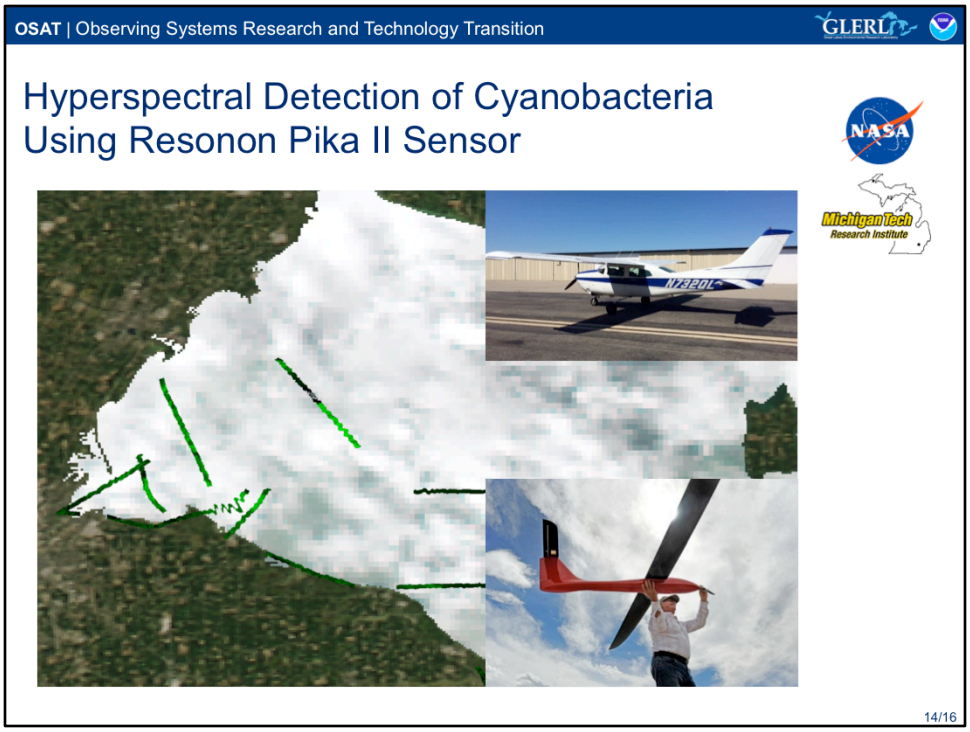
Continuous Parameters: SRP, Temp, Cond, CHL, PC, Turbidity, CDOM, pH, DO



R2A

- **Optical sensor data transitioned to GLOS HAB data portal in 2016**
- **Annex 4 assessment of phosphorus loads**

13/16



Hyperspectral system provides the ability to fly under clouds. As the 2015 HAB was forming in July, only a few good satellite images were available due to cloud cover.

Sensor: Spectral range 400-900 nm, Resolution 2.1 nm. Spatial resolution ~ 2 meters

Differentiation of Microcystis

- •Narrow reflectance peak centered at 560 nm
- •Absorption peak at approximately 625 nm with reflection peak at 650 nm
- •Both are indicated by reflection peak at approximately 710 nm

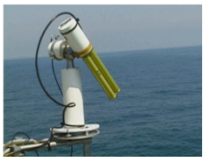
Project data used by Ohio EPA and water intake and beach managers. In 2016, weekly product in demonstration mode (TRL 6) for potential use in operational HAB Bulletin.

Collaborations: NOAA/OAR/ESRL, NASA Glenn Research Center, Michigan Tech Research Institute, Ohio Environmental Protection Agency

Future Work: Algal/HAB Classification, HAB mapping from aircraft and unmanned aerial system (UAS).

SUMMARY/FUTURE WORK

- SOAR project buoys developed as an extension of the ReCON project
- Hypoxia Warning/Monitoring System transitioned into operations through GLOS with industry partner
- Hypoxia and nutrient monitoring buoy data contributing to Annex 4 adaptive management feedback and HABs information for water intake managers
- Continue hyperspectral flyovers to detect, map and classify HABs - plan for UAS integration
- Continue optical property characterization and begin VIIRS / Sentinal 3 calibration/validation



15/16

UAS – Unmanned Aircraft Systems

The Visible Infrared Imaging Radiometer Suite (VIIRS) cal/val is being done in collaboration with NOAA National Environmental Satellite, Data, and Information Service (NESDIS)

European Space Agency Sentinal 3A satellite launched February 16, 2016 with the Ocean and Land Color Instrument (OLCI) providing a multi-spectral image capability needed for global HABs detection. Sentinal 3B scheduled for 2017.


Questions